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ECONOMIC INTELLIGENCE REPORT

THE STEAM AND HYDRAULIC TURBINE INDUSTRY OF THE USSR

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S-E-C-R-E-T

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CIA/RR 63

(ORR Project 36.519)

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THE STEAM AND HYDRAULIC TURBINE INDUSTRY OF THE USSR*

Summary

The steam and hydraulic turbine industry of the USSR employed 40,000 workers in 1954 and produced turbines valued at US $173 million with a capacity of 5.7 million kilowatts (kw). In addition, the industry produced replacement parts and auxiliary equipment that increased the value of production by about 20 percent. By comparison, the turbine industry of the US employed about 15,000 workers in 1954 but produced turbines valued at US $284 million with a capacity of 13 million kw.

The rate of production of the turbine industry in the USSR in 1954 was double that of the 1950 rate but slightly lower than the rate that would be required to meet the planned estimate. Production in 1955 is expected to meet planned figures, but it is doubtful if the industry will reach the total output level planned for the Fifth Five Year Plan (1951-55). The delay in the domestic production of turbines has a direct relationship to the underfulfillment of the investment program for the electric power industry, which is the principal user of turbines in the USSR.

Soviet plans for the expansion of the turbine industry indicate that industrial capacity will increase at an average rate of 10 to 15 percent per year. Assuming a maximum rate of increase, the Soviet production of turbines in 1960 would double the rate of production for 1954. Import requirements would be less, but the need for replacement parts for imported turbines will remain high.

The turbine industry of the USSR is highly concentrated geographically. Three plants account for 70 percent of all Soviet turbine production, and 90 percent of the production facilities are located in 3 cities -- Leningrad, Khar'kov, and Sverdlovsk. The large size of the plants, the requirements for highly skilled manpower, and the need for the heaviest means of transportation to haul parts, materials, and finished turbines are factors compelling this geographic concentration which makes the turbine industry strategically vulnerable.

* The estimates and conclusions contained in this report represent the best judgment of ORR as of 30 August 1955.

The production of the Soviet turbine industry has doubled in the last 5 years and probably will double again in the next 6 years. In 1955 the industry will produce turbines with a capacity of over 6 million kw, but requirements for materials will not increase proportionately, because of increased productivity, the output of lighter turbines, increased mechanization, and improvement in production technology.

I. Introduction.

A. General Description and Use of Turbines.

A turbine is a rotary engine actuated by the flow of fluid through curved blades. Turbines convert the thermal or kinetic energy of a fluid (usually gas, steam, or water) into mechanical energy, utilizing the energy transfer caused by the drop in fluid pressure or velocity across the blades of the turbine. The operation may be a reaction or an impulse principle or both.

Steam turbines range in size from about 20 horsepower (hp) to 200,000 kilowatts (kw) on 1 shaft. The weight of steam turbines ranges from about 150 pounds to 550 metric tons.*

Hydraulic turbines range in size from about 20 kw to 125,000 kw for a single unit. The weights of hydraulic turbines range from about 400 pounds to 1,600 tons.

Turbines are used in installations where a large amount of power is required in a relatively small package. Turbines are used almost exclusively for driving large power generators because they are the only mechanical-drive machines which can reasonably be built in single units of more than 15,000 hp. Approximately 77 percent of the capacity of all turbines made in the USSR is used in electric power-generation stations. The remaining 23 percent is used to drive pumps and fans or to propel ships.

* Tonnages are given in metric tons throughout this report.

Gas turbines discussed in this report are those industrial types that are used as stationary drives. Aircraft gas turbines are specifically excluded.

B. History. 1/*

1. Steam Turbines.

Turbine drives for generators were largely imported by the USSR until the end of the First Five Year Plan (1928-32). By 1933 a pronounced change had occurred, and only 342,000 kw of the total 870,000 kw of new generating equipment installed in the USSR were imported. In 1935, only one turbine was imported. Imports were resumed in 1936 and have remained at a substantial level even though production during nonwar years has continued to rise. There are indications that a change in the import trend will occur in the near future.

The trend toward more production of turbines in the USSR since 1933 resulted from the commissioning of several new plants. The Heavy Machine Plant imeni Kirov No. 185 in Leningrad began production of medium-range turbines in 1931, the Khar'kov Turbogenerator Plant (KhTGZ) imeni Kirov in Khar'kov began production of large turbines in 1934, the Nevsk Heavy Machinery Plant imeni Lenin No. 232 in Leningrad began the production of compressor-drive turbines in 1936, and the Ural Turbine Plant (UTZ) in Sverdlovsk had made large turbines by 1941. In 1936 the turbine industry of the USSR manufactured only standardized steam turbines that were simplified for mass production. 2/

The year 1936 was a milestone in the manufacture of turbines in the USSR. Until that time, the turbine manufacturers had produced only condensing steam turbines in series ratings up to 25,000 kw and 3,000 revolutions per minute (rpm) and 50,000 kw and 1,500 rpm. In 1936 a pilot-model 25,000-kw bleeder turbine was manufactured for serial production; a 50,000-kw, 3,000-rpm bleeder turbine was designed for production in 1937; and a 100,000-kw condensing turbine was designed, and later produced, in 1939. 3/

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From 1939 until 1945, scientific research institutes and design departments continued to work on high-pressure, high-temperature turbines. The Fourth Five Year Plan (1945-50) initiated a phase of turbine-building which emphasized thermal efficiency. High-pressure turbines of 90 atmospheres (atm) and 480° centigrade (C) up to 100,000 kw were produced, and a series of super-high-pressure model turbines was conceived. As of 1953 the majority of turbines installed in generating plants operated at 29 atm and 400° C. Twenty-two percent of the existing steam turbines in 1953 were of 90 atm and 480° C, and the present manufacture of these units will increase this total by about 6 percent per year. 4/

The next phase of turbine development, to be accomplished in the near future, will be the mass production of turbines of 100 atm and 500° C. Boilers are now being produced to meet these future demands. Beyond this stage of development there are future plans to design units of 170 atm and 500° C. Undoubtedly these units will be incorporated into existing power stations as topping turbines. There are no recent indications of Soviet interest in binary vapor cycles, which may mean that development is clothed in the secrecy of the atomic energy power program. The USSR was aware in 1950 of the advantages of binary vapor cycles and mercury vapor turbines which operated at pressures of up to 250 atm with temperatures up to 600° C.

2. Hydraulic Turbines.

After World War II the USSR purchased many hydraulic turbines to replace those destroyed during the war. The Soviet hydraulic turbine industry was able to make any type or size of machine required, but it was not able to produce its needs in quantity. By 1946 the Soviet industry had produced the first of six 75,000-kw turbines for the Dnieper hydroelectric power plant (GES). The 75,000-kw turbines was the largest unit produced in the USSR at that time. Since 1946, several large turbines of similar design and size have been made for other projects. When the short history of turbine technology in the USSR is considered, the present Soviet industry excels in the production of large hydraulic turbines. Turbines made for the Kuybyshev hydroelectric station in 1954 were of a maximum rating of 125,000 kw, equal in size to any produced in the world today, and designs are being made for larger units. 5/

C. Level of Technology and Research. 6/

Much of the work on turbine advancement is done by the Leningrad Metal Plant (LMZ) imeni Stalin No. 371; the Central Scientific Research Institute of Technology and Machine Building; the Central Scientific Research Institute for Boilers and Turbines; and the laboratories of several factories in Riga, Leningrad, Khar'kov, and the Moscow oblast.

Soviet progress in turbine design has been reflected in the increasing temperatures and pressures of steam turbines, and considerable progress has been made in increasing thermal efficiency. 7/ Before World War II, Soviet equipment operated at 420 pounds per square inch (psi) and 750° Fahrenheit (F), and such turbines constitute most of the present installed equipment. Since the war, many units of 1,400 psi and 900° F have been produced and are the present central station standard. Developments cover pressures of 2,500 to 3,700 psi at 1,000° F, and prototypes of these units have been produced. Steam turbine sizes have increased from 100,000 kw before the war to 150,000 kw after the war, and designs for 200,000-kw units are in process. Soviet steam turbines are now comparable in size to any in the world, with the exception of US units, which are slightly larger.

The USSR leads the world in the production of maximum-size hydraulic turbines. The turbines produced for the Kuybyshev hydroelectric station are as large as any in the world, and designs for 200,000-kw hydraulic turbines, presumably for the Angara River, are being prepared.

Research facilities of the USSR have not concentrated on pure research and theory of operation. They have taken a more practical approach which attempts to simplify production techniques, develop substitutes for critical materials, and facilitate mass production. Soviet turbine-blade designers have stressed precision-cast or rolled blades for steam turbines rather than blades milled from bar stock. 8/ Western manufacturers use drop-forge or rolled blades for similar applications. Large hydraulic turbine blades in Western countries are cast of solid alloy steel, but Soviet manufacturers prefer a cast-steel blade coated with alloy steel, which saves large quantities of alloy steel and makes casting easier. 9/ This practice offers the advantages of finishing blades in a copy mill rather than by hand and of easier machining. Such innovations may not coincide with the best Western practice but do produce an item of nearly equivalent performance, with significant savings in alloy metals and skilled labor. Advancements and modernizations of turbine construction are left to Western countries, and the USSR adopts scientific advances as soon as they are proved to be practical. In this manner the least effort is consumed in keeping abreast of world turbine developments.

Soviet technologists are frequently in advance of the world turbine industry in efforts to simplify the construction of units and to produce a quality turbine with the least possible amount of skilled labor, critical materials, and machine operations. They excel in rolled-plate welded construction, standardized construction, interchangeable parts, and similar mass-production methods. Even though the Russians coordinate efforts in research and technology to increase production and improve their product, they have yet to produce turbines of the high quality generally attained in Switzerland, West Germany, Sweden, the UK, and the US. This failure may be a direct result of too much emphasis on production and too little on quality, leading to maintenance which is excessive by Western standards. The Soviet finished product is different from that manufactured in Western countries. There are fewer regulating devices and controls built into the turbines, factors of safety are sacrificed, tolerances are greater, and designs of lower efficiency are acceptable if they require less material or skilled labor. A Soviet turbine requires fewer man-hours and critical materials to produce than US turbines of equal rating designed for durability and efficiency. The Soviet turbine is a sturdy product that will perform well under normal conditions, but overloads or fluctuating loads tend to have abnormally adverse effects. Soviet designs for high-efficiency, high-temperature turbines use more manpower and materials than are required for the US counterpart. The average Soviet turbine is much smaller than that produced in the US, 10/ and requirements for manpower and materials are relatively higher for smaller turbines. On the average, the turbine industry of the USSR requires more manpower and material to produce a given kilowatt output of turbines.

Soviet turbine designs have been standardized for years, and production technology has advanced sporadically, usually about 5 years behind that of the US. The efficiency of Soviet steam and hydraulic turbines also lags several years behind that of US counterparts because of manufacturing expediency, not because of inferior research or technology.

D. Importance.

The turbine industry of the USSR supplies the major portion of all prime movers for electric generating stations and naval ships. Approximately 77 percent of the turbine capacity produced in the USSR is used for generator drives in large power stations, and approximately 18 percent is used for ship propulsion units.

The importance of the turbine industry of the USSR to the civilian sector of the economy is measured directly by the essential demand for electric power. Electrification is recognized as one of the most important factors in increasing industrial productivity, and major emphasis in the USSR has been placed on the expanded utilization of electrical energy, both for civilian consumption and in industry. 11/ The civilian economy could continue to operate without a continuing supply of turbines, but the modern industrial economy could not. Maximum utilization of existing generating capacity without replacements would rapidly result in decreased availability of power for industry.

The importance of the turbine industry to the military sector is based primarily on the expanding power requirements of the Soviet defense industry. The Soviet Navy is dependent upon the turbine industry to supply the propulsion units for its warships. A small number of stationary gas turbines are also used by Soviet Army field forces for experimental purposes.

E. Comparison between the US and the USSR.

The turbine industry of the USSR required 40,000 employees and an industry running at 100 percent of capacity to produce turbines with a capacity of 5.7 million kw and a value of US $173 million in 1954. The turbine industry of the US required about 15,000 employees and an industry running at about 80 percent of capacity to produce turbines with a capacity of 13 million kw and a value of US $284 million during the same year. The disproportion in favor of the US reflects the greater efficiency of US plants, the use of more expensive materials, and the greater skill of US labor. It is also based on the difference in the size of turbines produced by the two countries. The capacity of the average turbine produced in the USSR is 25,000 kw, whereas the capacity of the average turbine in the US is 100,000 kw. The larger turbines, although more complicated, are more efficient, are less expensive per kw, and require a proportionately fewer number of employees to produce.

II. Organization. 12/

Eight ministries in the USSR control plants that are producing or have produced turbines as a finished item. Only one of these ministries, the Ministry of Heavy Machine Building, has a main administration

devoted to the production of turbines, the Main Administration of the Turbine Industry (Glavturboprom), which has 4 of the 5 basic turbine plants under its jurisdiction.

The various branches of the Soviet engineering industries are so elaborately interwoven that it is impossible to draw clear organizational dividing lines between component manufacturers, assemblers, and other contributors. Of the large producers, the Ministry of Heavy Machine Building and the Ministry of Transport Machine Building produce complete turbines, components, and auxiliaries in their factories, and the Ministry of Shipbuilding produces turbines from components supplied by other ministries. Less important producers in the Ministry of Automobile, Tractor, and Agricultural Machine Building; the Ministry of Electric Power Stations; the Ministry of Machine and Instruments Building; the Ministry of the Petroleum Industry; and the Ministry of Local Industry produce small turbines. About half of the plants under these ministries produce all their own parts and components. The other producers require a supply of various parts and components from other ministries -- usually from the Ministry of Heavy Machine Building or from the Ministry of Transport Machine Building.

Within individual ministries, each plant is given a yearly plan for industrial production, specifying the volume of end products and the volume of components products to be produced. This plan is established by the State Planning Commission (Gosplan) and administered by the ministry to which the plant belongs. In exceptional cases a plant has been known to have become directly responsible to the Ministry of Heavy Machine Building, but it is usually responsible to the Main Administration of the Turbine Industry. 13/

As applied to the turbine industry, the planning system does not always produce the desired results, largely because of the insistence on fulfilling or overfulfilling plans established arbitrarily at higher echelons without proper consideration for realities. Managers are therefore tempted to concentrate on quantity and on the easier targets, which leads to unsatisfactory quality and to bottlenecks. 14/

III. Production, Capacity, and Trade.

A. Production. 15/

Estimated production figures for 1954 for selected turbine plants in the USSR are given in Table 1. A complete listing of all known plants producing turbines in the USSR is given in Table 21,* Appendix B.

Table 1

Estimated Production for Selected Turbine Plants in the USSR 1954

Thousand KW

Plant	Production
Leningrad Metal Plant (LMZ) imeni Stalin No. 371	1,900
Heavy Machine Plant imeni Kirov No. 185	400
Shipyard imeni Zhdanov	200
Nevsk Heavy Machinery Plant imeni Lenin No. 232	400
Khar'kov Turbogenerator Plant (KhTGZ) imeni Kirov	1,000
Ural Turbine Plant (UTZ)	600

The figures presented in Tables 1 and 21 do not represent the entire production of the turbine industry of the USSR. Three methods** were used to derive industrial production, only one of which involved the analysis of production in individual plants.

Tables 2, 3, and 4*** give estimates of the total production of turbines in the USSR for 1940 and 1945-54.

* P. 47, below.
** For methodology, see Appendix C.
*** Tables 2, 3, and 4 follow on pp. 10, 11, and 12, respectively.

Table 2

Estimated Production of Hydraulic Turbines in the USSR a/ 1940, 1945-54, and 1955 Plan

Year	Unit Output (Thousand Kw)	Value	
		Million 1953 Rubles	Million 1953 US $
1940	447	89	22
1945	75	15	4
1946	175	35	9
1947	350	70	18
1948	420	84	21
1949	200	40	10
1950	160	32	8
1951	395	79	20
1952	490	98	25
1953	660	132	33
1954	1,200	240	60
1955 Plan	1,250	250	63

a. 16/. The estimates of production also include the value of repairs.

B. Imports.

The USSR has imported numerous turbines and turbine parts from the European Satellites and from the West. The magnitude of total imports has remained relatively constant over the years from 1951 to 1954, although the established trade pattern has changed slightly. Switzerland, West Germany, and the UK are not so important as exporters of turbines to the USSR as they were in the past. Sweden, Austria, East Germany, and Czechoslovakia are now the most important suppliers of turbines to the USSR. Estimated imports of turbines to the USSR in 1954 are given in Table 5.*

* Table 5 follows on p. 13.

Table 3

Estimated Production of Steam Turbines in the USSR a/ 1940 and 1945-54

Year	Unit Output (Thousand Kw)	Value	
		Million 1953 Rubles	Million 1953 US $
1940	1,000	110	25
1945	573	63	14
1946	745	82	19
1947	1,170	129	29
1948	1,370	151	34
1949	2,360	260	59
1950	2,600	286	65
1951	2,860	315	72
1952	3,090	340	77
1953	4,320	475	108
1954	4,500	495	113

a. 17/. The estimates of production also include the value of repairs.

C. Exports:

In the past the USSR has suffered severe shortages of turbines, and exports were negligible. Although imports are still greater than known exports, the level of current production has now enabled the USSR to export turbines to the European Satellites, Communist China, and some non-Soviet Bloc countries. The estimated exports of turbines from the USSR in 1954 are given in Table 6.* Whether the turbines were originally imported, manufactured, or rebuilt cannot readily be determined, but there is evidence to indicate that the major portion of Soviet export commitments are met with the imports received from the Satellites and the West. The underlying reasons are probably the desire of the Russians to prevent interference with their standardized production lines and to avoid any

* Table 6 follows on p. 13.

Table 4

Estimated Employment in the Turbine Industry and Production of Steam and Hydraulic Turbines in the USSR a/ 1940 and 1945-54

Year	Number of Employees	Unit Output (Thousand Kw)	Value	
			Million 1953 Rubles	Million 1953 US $
1940	18,800	1,447	199	47
1945	18,000	650	78	18
1946	18,000	920	117	28
1947	20,000	1,520	199	47
1948	21,500	1,790	235	55
1949	23,000	2,560	300	69
1950	24,000	2,760	318	73
1951	26,540	3,255	394	92
1952	28,380	3,580	438	102
1953	35,800	4,980	607	141
1954	40,000	5,700	735	173

a. 18/. The estimates of production also include the value of repairs.

further obligation to produce spare parts for non-Soviet-manufactured turbines if imports were cut off. On the other hand, the Satellites that can establish proper barter or credit terms probably would prefer turbines and parts produced by Western or Satellite "old line" producers because the major part of their existing equipment had been supplied by the "old line" producers. Turbines produced by the USSR are standardized, whereas other suppliers build turbines for specific purposes to customer requirements.

Table 5

Estimated Imports of Turbines to the USSR by Capacity and Value a/ 1954

Country of Origin	Capacity (Thousand Kw)	Value b/ (Thousand 1953 US $)
East Germany	150	3,000
Czechoslovakia	300	6,000
Hungary	60	3,000
Switzerland	Negligible	2,300
Sweden	225	11,250
Italy	25	4,000
UK	25	2,000
Austria	200	10,000
Total	985	41,550

a. 19/. These figures include imports for re-export purposes.
b. Value includes turbine parts. The total cannot therefore be used to develop price per kilowatt of turbines.

Table 6

Estimated Exports of Turbines from the USSR by Capacity and Value a/ 1954

Country of Destination	Capacity (Thousand Kw)	Value (Thousand 1953 US $)
Albania	15	300
Rumania	50	625
Bulgaria	75	1,250
Poland	200	4,500
Communist China	250	5,000
Other	25	625
Total	615	12,300

a. 20/

D. Expansion of Production.

The production of turbines in the USSR is expected to increase after 1955. Long-range plans for the electrification of the country require that the capacities of power stations increase at a rate of approximately 12 percent per year to keep pace with power-generation requirements. 21/ The turbine industry of the USSR would need to expand production more than 12 percent to supply the capacities required in the power stations. The trend in the manufacture of turbines is toward larger units, and the design offices of two major turbine plants are busy with designs that exceed in size any unit yet produced.

Principal turbine plants have received new machine tools of huge proportions, designed solely for special operations on giant turbine parts. These tools will allow the mass production of parts that are usually so difficult to manufacture that they become limiting factors in the production of turbines. 22/

To meet the demands of consumers, the production of the turbine industry of the USSR in 1960 should double the rate in 1954. The expansion in the industry is expected to be accomplished largely through greater production from existing plants, and this burden will fall on the large plants at Leningrad, Khar'kov, and Sverdlovsk.

The USSR can use more turbines than it produces, but it is possible that the USSR could become an exporter of turbines in the competitive world market during the next 5 years, particularly in the field of large hydraulic turbines. It is also possible that the Soviet economic system plus low-cost mass production of turbines could place a low-cost turbine of acceptable quality on the world market, which would undersell anything made in the West.

E. Use Patterns.

The most recent estimates of the production of turbines in the USSR reveal that the requirements for domestic power plants and naval installations can be met from domestic sources, despite continuing heavy imports for domestic use and export commitments. Table 7* gives Soviet requirements for the production of turbines in 1954 and indicates that Soviet requirements closely parallel production. These requirements were derived by adding turbine requirements for each

* Table 7 follows on p. 15.

Table 7

Requirements for the Production of Turbines in the USSR
1954

Use	Capacity (Thousand Kw)	Percent of Total
Central station power generation	3,750	76.5
Ship propulsion and auxiliaries	885	18.0
Pump and fan drives	200	4.1
Miscellaneous small units	70	1.4
Total	4,905	100.0

sector of Soviet industry for 1953. Soviet requirements for turbines with a capacity of 4.9 million kw in 1954 are to be compared with the estimated production of turbines with a capacity of 5 million kw in 1954. The 2 estimates were derived by independent means, and both are subject to a 15-percent margin of error; thus the magnitudes may be considered equal.

Table 8* gives a comparison of US and Soviet electric power plants in terms of number of plants and capacity and Table 9** gives the production of marine steam turbines in the USSR in 1949-55.

IV. Input Requirements.

A. Materials.

1. Requirements.

Input coefficients for turbines vary with both the size and the type of product. Factors affecting the inputs to steam turbines are pressure, speed, temperature, exhaust conditions, type and speed of prime mover, and design principle. Steam turbines in the

* Table 8 follows on p. 16.
** Table 9 follows on p. 17.

Table 8

Comparative Estimate of Electric Power Plants in the US and the USSR by Number and Capacity a/
1 January 1954

Capacity Grouping of Known Plants (Thousand Kw)	All Plants						Thermal Electric Plants				Hydroelectric Plants			
	Number (Unit)		Capacity (Million Kw)		Percent of Total Capacity		Number (Unit)		Capacity (Million Kw)		Number (Unit)		Capacity (Million Kw)	
	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR	US	USSR
Over 300	57	10	26.1	4.0	24.3	14.3	50	8	21.3	3.0	7	2	4.8	1.0
201 to 300	52	11	13.1	3.0	12.2	10.7	43	9	10.9	2.4	9	2	2.2	0.6
101 to 200	157	23	22.6	4.0	21.1	14.3	124	23	18.2	3.3	33	5	4.4	0.7
51 to 100	208	48	15.0	3.9	14.0	13.9	147	37	10.7	3.0	61	11	4.3	0.9
11 to 50	314	230	18.9	6.1	17.6	21.8	602	190	13.7	5.1	212	40	5.2	1.0
Subtotal	1,288	327	95.7	21.0	89.2	75.0	966	267	74.8	16.8	322	60	20.9	4.2
All others	N.A.	N.A.	11.6	7.0	10.8	25.0	N.A.	N.A.	9.5	5.6	N.A.	N.A.	2.1	1.4
Total b/	N.A.	N.A.	107.3	28.0 c/	100.0	100.0	N.A.	N.A.	84.3	22.5	N.A.	N.A.	23.0	5.6

a. 23/
b. Range of error: US, plus or minus 2 percent; USSR, plus or minus 10 percent. The total capacity of electric power plants in the US is divided into 78 percent thermal electric and 22 percent hydroelectric and in the USSR, 80 percent thermal electric and 20 percent hydroelectric.
c. Installed capacity in January 1955 is estimated to have been 32 million kw. Installed capacity in January 1953 is estimated to have been 25 million kw. Installed capacities are maximum estimates.

Table 9

Production of Marine Steam Turbines in the USSR [a]
1949-54 and 1955 Plan

Thousand Kw

Plant	Location	Ship Type	1949	1950	1951	1952	1953	1954	1955 Plan
Ural Turbine Plant (UTZ)	Sverdlovsk	DD	78	104	104				
		DC				60	89	89	89
Nevsk Heavy Machinery Plant imeni Lenin No. 232	Leningrad	DD	[b]	[b]	[b]				
		DC				30	60	60	30
Shipyard imeni Zhdanov	Leningrad	DD	104	209	209	209	157	157	209
		DC					30		
Leningrad Metal Plant (LMZ) imeni Stalin No. 371	Leningrad	DD	183	235	363	157	157	209	209
		CL	45	89	134	89	45	45	[c]
Heavy Machine Plant imeni Kirov No. 185	Leningrad	DD	157	157	314	157	104	52	157
		DC					30	119	60
		CL	45	89	134	89	45	[c]	[c]
Khar'kov Turbogenerator Plant (KhTGZ) imeni Kirov	Khar'kov	DD	261	261	261	104			
		DC				89	119	149	179
		CL	89	89	89	89	45	45	[c]
Total		DD	783	966	1,253	627	418	418	575
		DC				179	328	417	358
		CL	179	267	357	267	135	90 [c]	[c]
Grand total			962	1,233	1,610	1,073	881	925 [c]	933 [c]

a. [24]
b. Auxiliary drives only.
c. Capacity available.

USSR have been standardized to the degree that these factors may be restricted to type, size, and pressure, and a single typical product mix may be used.

Factors affecting the inputs to hydraulic turbines essentially are head, capacity, and design of turbine. Hydraulic turbines are so dependent upon the conditions of available water that each power plant installation becomes a custom design. Production of hydraulic turbines in 1954 is used as a typical year's product mix. The input data compiled for 1954 agree closely with that for 1951. The product mix differed in these 2 years, but in both years it included a major portion of large, low-head, Francis-type turbines.

Material input requirements for the production of Soviet steam and hydraulic turbines are given in Table 10.* US material inputs are given in Tables 13 and 14,** Appendix A.

2. Sources of Supply.

The USSR is capable of supplying its own needs for all materials required to produce turbines but does not produce all the turbines and turbine parts used in the USSR. The USSR imports special parts, such as blades and alloy steel rotors, from the European Satellites and the West instead of producing all these parts with limited Soviet facilities.

Many turbines installed in the USSR were made in the West, and it is easier for the USSR to purchase replacement parts for these turbines than to copy the parts. Most manufacturers will not approve having their product copied and have refused to supply design information to the Russians when asked, but will supply unlimited spare parts for turbines which they have manufactured.

B. Power.

The power required per kilowatt to produce a turbine in the USSR very nearly approaches the power requirements in the US for similar production. More man-hours per kilowatt output are required in the USSR because the average turbine is smaller, and small units require a greater

* Table 10 follows on p. 19.
** Pp. 26 and 27, respectively, below.

Table 10

Material Input Requirements for Steam and Hydraulic Turbines in the USSR
1954

Material	Steam Turbines		Hydraulic Turbines a/	
	Pounds per Kw	Pounds per Year	Pounds per Kw	Pounds per Year
Carbon steel				
Bars and shapes	0.485	2,182,500	2.33	2,796,000
Sheet and strip	0.206	927,000	0.24	288,000
Plate	4.217	18,976,500	11.26	13,512,000
Forgings	0.361	1,624,500	3.06	3,672,000
Castings	0.845	3,802,500	18.73	22,500,000
Other carbon	0.399	1,795,500	0.16	192,000
Alloy steel				
Stainless	0.845	3,802,500	0.50	600,000
Other alloy	2.413	10,858,500	0.03	3,600
Nonferrous metal				
All types	0.236	1,062,000	0.55	660,000
Total	10.007	45,031,500	36.86	44,232,000

a. The weight of hydraulic turbines includes the base.

number of man-hours per kilowatt. These two factors appear to balance the greater utilization of electric power per man in the US. The USSR annually requires 128 million kilowatt-hours (kwh) to supply the needs of the turbine industry.

C. Manpower.

The turbine industry of the USSR employs highly trained skilled labor. The turbine industry employed an estimated 40,000 employees of all types in 1954. Employment data for 1940 and 1945-54 are given in Table 4.*

V. Capabilities, Vulnerabilities, and Intentions.

A. Capabilities.

The total capacity of turbines produced in the USSR in 1954 is estimated to have been 5.7 million kw. The majority of the units were new, although the capacity of reworked turbines is included in the total. The Soviet capacity to produce turbines has increased beyond the normal expected rate, doubling in the last 5 years. The increase from 1951 to 1955 will probably meet Plan proposals for turbine production, and it is estimated that by 1960 the USSR could double 1954 production by expanding and modernizing existing facilities.

At present the USSR imports a small number of turbines to fill domestic needs, but by 1960 it will be able to meet domestic needs without imports. It is believed that the USSR will continue to import certain special parts and certain special types of turbines where this is more expedient rather than interfere with the domestic production of standard units.

B. Vulnerabilities.

The very nature of the heavy specialized production machinery used in the production of turbines requires a highly skilled labor force in a large specialized plant, and plants are not readily moved from one geographic area to another. The turbine industry of the USSR is concentrated in Leningrad, where 58 percent of the Soviet turbines are manufactured. The LMZ alone accounts for 38 percent of

* P. 12, above.

the total Soviet production. The Leningrad area probably produces 75 percent of all forged turbine blades, and the Novo Kramatorsk Heavy Machine Building Plant imeni Stalin in Electrostal' accounts for all large cast-alloy blades for hydraulic turbines. Of the other 2 centers of production, Khar'kov produces 20 percent, and Sverdlovsk produces 12 percent. The concentration of turbine and blade production in a few large centers makes the turbine industry vulnerable. Three plants account for 70 percent of production, and 3 cities account for 90 percent of production.

Large turbine plants depend upon suppliers of components and materials. These suppliers are usually remote from the assembly plant, and rail transportation is required to move these large parts from supplier to plant. Any interruption in the normal flow of goods would have widespread results, as plant production schedules permit little or no surplus inventory. Interruptions in the rail delivery of steel castings and forgings would prevent plant scheduling of production. Manufacturers of small and medium turbines would be least affected by interference in rail delivery or by interruptions in supply.

The USSR is estimated to import turbines with a capacity of 985,000 kw and to export turbines with a capacity of 615,000 kw. Net imports are supplemented by many spare parts made of special materials. Interdiction of imports would have a disproportionate effect; the Soviet industry would have to produce more than 370,000 kw of turbines, for many turbines in the USSR were made by Western manufacturers and the parts required are often not made in the USSR. Usually the turbines and parts are of a unique type, and the USSR is not equipped to produce these special items. The burden of producing these items would affect heavy industry, but it would not undermine expansion plans. The turbine industry of the USSR is expanding rapidly, and the effects of embargo would diminish with time.

C. Intentions.

The Soviet Fifth Five Year Plan announced that the turbine industry of the USSR intends to raise production in 1955 over that of 1950. 25/ The figures were given in percentages, with no statement of actual capacity intended and no figures for the intervening years. These plans are estimated to indicate a 1955 goal of 1.25 million kw of hydraulic turbines and 6 million kw of steam turbines. The

turbine industry probably will achieve the planned goal for 1955 for rate of production and may achieve the Plan goal for the production of individual units of the larger sizes. Soviet planners in 1950 announced the intent to double the 1950 power-generating capacity by the end of 1955, but recent statements of M.G. Pervukhin (former Minister of Electric Power Stations and the Electrical Industry) have been interpreted to imply that this goal has been lowered. It is likely that many small- and medium-size turbines, whose production was planned, will not be made, for every effort is being expended to produce turbines of larger sizes. 26/ The production plans for the years from 1951 to 1955 are not known, but any failure to achieve planned installed capacity in power plants probably is the result of a deficiency of production or of imports of turbines. Plan goals for intervening years probably have not been achieved.

The production of turbines by the Soviet turbine industry probably will continue to increase at an average rate of 10 to 15 percent per year until about 1965.

APPENDIX A

TURBINE DATA AND INPUT COEFFICIENTS

I. Introduction.

Technical data pertaining to the physical description, costs of production, and material inputs 27/ for the production of steam and hydraulic turbines in both the US and the USSR are given in Tables 11-20.*

* Tables 11-20 follow on pp. 24-35.

Table 11

Characteristics of Steam Turbines in the USSR a/

Type	Size (Thousand Kw)	Weight (Metric Tons)	Weight (Pounds per Kw)	Cost (Million 1949 Rubles)	Product Mix Ratio
VK 100-2	100	290	6.4	6.0	1
AK 50-1	50	260	11.4	4.0	1
VK 50-1	50	166	7.3	3.8	1
VPT 25-3	25	154	13.6	3.5	1
AP 25-2	25	132	11.6	2.7	6
VT 25-4	25	143	12.6	2.9	1
VP 25-1	25	89	7.8	2.75	1
VP 25-2	25	90	7.9	2.85	1
AP 6	6	52	19.1	1.45	2
AP 6-11	6	30	11.0	0.93	1
AT 25-2	25	90	7.9	2.7	10
AK 12	12				6

a. 28/. These figures are based on the 1949 Soviet price list.

Table 12

Characteristics of Hydraulic Turbines in the USSR a/

Type	Size (Thousand Kw)	Weight of Turbine (Metric Tons)	Weight of Base (Metric Tons)	Cost of Turbine (Million 1949 Rubles)	Cost of Base (Million 1949 Rubles)	Total Weight (Metric Tons)	Total Weight (Pounds per Kw)
Francis F 82VM300	38.5	130	117	1.3	0.5	247	14.1
Francis F 123VN550	75	415	120	4.12	0.98	535	15.7
Kaplan K 91VB900	65	1,020	290	10.4	1.6	1,310	44.5
Kaplan K 245VB360	12.5	133	14.2	2.42	0.105	1,472	25.9
Kaplan K 91VB800	46.0	790	190	8.0	1.26	980	46.9

a. 29/. These figures are based on the 1949 Soviet price list.

Table 13

Material Requirements for the Production of Steam Turbines in the US a/

Material	Size of Unit (Kw) 5,000	10,000	50,000	100,000
Carbon steel (pounds per kw)				
Bars and shapes	0.639	0.606	0.186	0.096
Sheet and strip	0.506	0.258	0.136	0.067
Plate	8.049	5.266	1.031	0.527
Forgings	0.921	0.449	0.918	0.274
Castings	0.897	1.058	0.301	0.153
Other carbon	0.276	0.498	0.761	0.534
Alloy steel (pounds per kw)				
Stainless	0.581	1.054	0.587	0.584
Other alloy	0.670	3.015	4.179	2.462
Nonferrous metal (pounds per kw)				
All types	0.230	0.296	0.081	0.075
Total weight (pounds per kw)	12.769	12.5	8.180	4.74
Manpower (man-hours per kw)	8.52	8.35	3.24	3.34
Cost (dollars per kw)	30	29.66	21.33	17.33

a. 30/. Data are based on US 1952 practice.

Table 14

Material Requirements for the Production of Hydraulic Turbines in the US a/

Pounds per Kw

Material	Size of Unit (Kw)			
	3,750	7,500	37,500	75,000
Carbon steel				
Bars and shapes	1.34	1.94	2.0	0.8
Sheet and strip	0.67	0.2	0.134	0.1
Plate	6.7	9.38	11.52	8.04
Forgings	1.39	2.55	1.88	1.55
Castings	15.81	15.61	1.69	7.76
Other carbons	0.8	0.134	0.24	0.20
Alloy steel				
Stainless	0.08	0.035	0.8	0.34
Other alloy	0.134	0.027	0.03	0.016
Nonferrous metal				
All types	0.67	0.462	0.34	0.268
Total weight	24.38	30.34	18.73	19.077

a. 31/. The weights shown do not include the turbine base. Data are based on US 1952 practice.

Table 15

Characteristics of Standard Condensation Steam Turbines in the USSR a/
1954

Number	Type	Initial Parameter of Steam: Pressure (Atm)	Initial Parameter of Steam: Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Governor Selector Pressure (Atm): 1st Selector	Governor Selector Pressure (Atm): 2d Selector	Quantity of Exhaust Steam (Tons per Hour): 1st Selector	Quantity of Exhaust Steam (Tons per Hour): 2d Selector	Feed Water Temperature (C)	Turbine Oil Cooling Water Temperature (C)
1	AT 12	29	400	12	3,000	1.2 to 2.5		60		(Adjusted to technical conditions on delivery of turbine.)	
2	AK 25	29	400	25	3,000						
3	AT 25	29	400	25	3,000	1.2 to 2.5		100			
4	AP 25	29	400	25	3,000	6 to 8		150			
5	AK 50	29	400	50	3,000						
6	AK 50	29	400	50	1,500						
7	AP 0.75	35	435	0.75	3,000 or 1,000	4 to 6		7		150	20
8	AK 1.5	35	435	1.5	3,000 or 1,000					150	20
9	AT 1.5	35	435	1.5	3,000 or 1,000	1.2 to 2.5		9		150	20
10	AP 1.5	35	435	1.5	3,000 or 1,000	4 to 6		12		150	20
11	AK 2.5	35	435	2.5	3,000 or 1,000					150	20
12	AT 2.5	35	435	2.5	3,000 or 1,000	1.2 to 2.5		14		150	20
13	AP 2.5	35	435	2.5	3,000 or 1,000	4 to 6		18		150	20
14	AK 4	35	435	4	3,000					150	20
15	AT 4	35	435	4	3,000	1.5 to 2.5		22		150	20
16	AP 4	35	435	4	3,000	4 to 6		25		150	20
17	AK 6	35	435	6	3,000					150	20
18	AT 6	35	435	6	3,000	1.2 to 2.5		35		150	20
19	AP 6	35	435	6	3,000	4 to 6		40		150	20
20	AK 12	35	435	12	3,000					150	15
21	AT 12	35	435	12	3,000	1.2 to 2.5		65		150	20
22	APT 12	35	435	12	3,000	1.2 to 2.5	8 to 13	40	50	150	20
23	VPT 12	90	480	12	3,000	1.2 to 2.5	8 to 13	30	40	215	20
24	VK 25	90	480	25	3,000					215	15
25	VT-25	90	480	25	3,000	1.2 to 2.5		100		215	20
26	VPT 25	90	480	25	3,000	1.2 to 2.5	8 to 13	60	80	215	20
27	VK 50	90	480	50	3,000					215	10 to 15
28	VK 100	90	480	100	3,000					215	10 to 15

a. According to GOST No. 3618-47.

Table 16

Characteristics of Steam Turbines with Back-Pressure in the USSR a/*

Number	Type	Initial Parameter of Steam: Pressure (Atm)	Initial Parameter of Steam: Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Back-Pressure (Atm)	Range of Fluctuation of Back-Pressure (Atm)
1	AR-0.75	15	350	0.75	1,000 or 3,000	3	2 to 4
2	AR-0.75	15	350	0.75	1,000 or 3,000	6	4 to 7
3	AR-1.5	15	350	1.5	1,000 or 3,000	3	2 to 4
4	AR-1.5	15	350	1.5	1,000 or 3,000	6	4 to 7
5	AR-2.5	15	350	2.5	1,000 or 3,000	3	2 to 4
6	AR-2.5	15	350	2.5	1,000 or 3,000	6	4 to 7
7	AR-0.75	35	435	0.75	1,000 or 3,000	3	2 to 4
8	AR-0.75	35	435	0.75	1,000 or 3,000	6	4 to 7
9	AR-1.5	35	435	0.75	1,000 or 3,000	6	2 to 4
10	AR-1.5	35	435	1.5	1,000 or 3,000	6	4 to 7
11	AR-1.5	35	435	1.5	1,000 or 3,000	11	8 to 13
12	AR-1.5	35	435	1.5	1,000 or 3,000	15	13 to 17
13	AR-2.5	35	435	2.5	1,000 or 3,000	3	2 to 4
14	AR-2.5	35	435	2.5	1,000 or 3,000	6	4 to 7
15	AR-2.5	35	435	2.5	1,000 or 3,000	11	8 to 13
16	AR-2.5	35	435	2.5	1,000 or 3,000	15	13 to 17
17	AR-4	35	435	4	3,000	3	2 to 4
18	AR-4	35	435	4	3,000	6	4 to 7
19	AR-4	35	435	4	3,000	11	8 to 13

* Footnote for Table 16 follows on p. 30.

Table 16

Characteristics of Steam Turbines with Back-Pressure in the USSR a/
(Continued)

Number	Type	Initial Parameter of Steam: Pressure (Atm)	Initial Parameter of Steam: Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Back-Pressure (Atm)	Range of Fluctuation of Back-Pressure (Atm)
20	AR-4	35	435	4	3,000	15	13 to 17
21	AR-6	35	435	6	3,000	3	2 to 4
22	AR-6	35	435	6	3,000	6	4 to 7
23	AR-6	35	435	6	3,000	11	8 to 13
24	AR-6	35	435	6	3,000	15	13 to 17
25	AR-6	90	500	6	3,000	31	29 to 33
26	AR-6	90	500	6	3,000	37	36 to 38
27	VR-12	90	500	12	3,000	11	8 to 13
28	VR-12	90	500	12	3,000	18	15 to 21
29	VR-12	90	500	12	3,000	31	29 to 33
30	VR-25	90	500	25	3,000	18	15 to 21
31	VR-25	90	500	25	3,000	31	29 to 33

a. According to GOST No. 3678-47.

Table 17

Characteristics of Nonstandard Types of Steam Turbines in the USSR

Number	Type	Plant	Initial Parameter of Steam		Maximum Power (Thousand Kw)	Rpm of Turbine Shaft	Governor Selector Pressure (Atm)		Quantity of Exhaust Steam (Tons per Hour)		Back-Pressure (Atm)	Expenditure of Steam by the Turbine (Tons per Hour)
			Pressure (Atm)	Temperature (C)			1st Selector	2d Selector	1st Selector	2d Selector		
1	AK 100	LMZ	29	400	100	3,000						460
2	AK 100	KhTGZ	29	400	100	1,500						450
3	AK 50-1	LMZ	29	400	50	1,500						232
4	AP 50	LMZ	29	400	50	3,000	6 to 8		200			320
5	VR 25-1	LMZ	125	450	25	3,000					34	378
6	APT 12-2	KhTGZ	29	400	12	3,000	1.2 to 2.5	12 to 13	40	75		143
7	APR 12-2	LMZ	29	400	12	3,000	11.0		120		1 to 1.3	175
8	AK 12	Kirov	29	400	12	3,000						58
9	APT 12-1	Kirov	29	400	12	3,000	1.2 to 2.5	7 to 8	40	33		103
10	AP 6-1	NZL	29	400	6	3,000	5 to 6		35			55
11	AP 6-2	NZL	29	400	6	3,000	6 to 7		35			55
12	AK 6-1	LMZ	1.2	110 to 130	6	3,000						94
13	AP 4	NZL	29	400	4	5,000	5 to 6		25			39
14	AK 3.5	Kirov	16	350	3.5	3,000						19
15	AP 2.5-1	NZL	20	350	2.5	5,000	5 to 6		20			31
16	AP 1.5	NZL	20	350	1.5	5,000	5 to 6		15			

Table 18

Characteristics of Steam Turbines for Compressor and Pump Drives in the USSR

Type	Construction	Nominal Data				Limiting Data		Steam Rate (Tons per Hour)	Complete Weight (Metric Tons)		Cost (Million 1950 Rubles)
		Pressure (Atm)	Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Power (Thousand (Kw)	Rpm of Turbine Shaft		Net	Gross	
AKV 12	Single cylinder condensing impulse turbine with 1 curtis wheel and 16 pressure stages	35	435	12	3,000	9.2 12.4	2,400 3,500	40.5 58	85.3	93.3	2.2
AKV 9	Single cylinder condensing impulse turbine with 1 curtis wheel and 16 pressure stages	35	435	9	3,000	6.6 10	2,400 3,500	31.4 49	80.0	88.0	2.1
AKV 6	Single cylinder condensing impulse turbine with 1 curtis wheel and 16 pressure stages	35	435	6	3,000	4.8 7.1	2,400 3,500	21.3 35	45.3	51.0	1.4
AKV 4	Single cylinder condensing impulse turbine with 1 curtis wheel and 15 pressure stages	35	435	4	3,000	3.2 4.8	2,400 3,500	15 24	45.3	51	1.35
OK 500-1	Single cylinder condensing impulse turbine with 1 curtis wheel and 2 pressure stages forming two 2-crown wheels	10	240	0.45	3,000	0.35 0.45	2,950 3,300	5	3.0	3.7	0.24
OK 500-2	Single cylinder condensing impulse turbine with 1 curtis wheel and 2 pressure stages forming two 2-crown wheels	10	240	0.35	3,000	0.25 0.35	2,950 3,300	3.9	3.0	3.7	0.24

Table 19

Characteristics of Standard Condensation Steam Turbines in the USSR
1950

Type	Construction	Initial Parameter of Steam: Pressure (Atm)	Initial Parameter of Steam: Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Governor Selector Pressure (Atm)	Steam Rate (Tons per Hour)	Exhaust Pressure (Atm)	Heat Rate (Kg of Steam per Kwh)	Weight (Metric Tons): Net	Weight (Metric Tons): Gross	Cost F.O.B. Plant (Million 1949 Rubles)
Increased Pressure												
AK 50-1	Single cylinder condensing	29	400	50	1,500		232		4.51	241	260	4
AP 25-2	Single cylinder condensing with industrial extraction	29	400	25	3,000		150	10	10.72	120	132	2.7
AP 6	Single cylinder condensing with industrial extraction	35	435	6	3,000		40	5	8.88	47	52	1.45
AP 6-11	Single cylinder with industrial heating	35	435	6	3,000	11			16.3	26	30	0.93
High Pressure												
VK 100-2	Two cylinder condensing	90	500	100	3,000				3.95	270	290	6
VK 50-1	Single cylinder condensing	90	500	50	3,000				3.95	160	166	3.8
VT 25-4	Single cylinder condensing with heating extraction	90	500	25	3,000		100	1.2	5.72	130	143	2.9
VPT 25-3	Single cylinder condensing with 2 regulating extractions: industrial and heating	90	500	25	3,000		$\frac{72}{54}$	$\frac{10}{1.2}$	7.03	140	154	3.5

Table 19

Characteristics of Standard Condensation Steam Turbines in the USSR
1950
(Continued)

Type	Construction	Initial Parameter of Steam: Pressure (Atm)	Initial Parameter of Steam: Temperature (C)	Power (Thousand Kw)	Rpm of Turbine Shaft	Governor Selector Pressure (Atm)	Steam Rate (Tons per Hour)	Exhaust Pressure (Atm)	Heat Rate (Kg of Steam per Kwh)	Weight (Metric Tons): Net	Weight (Metric Tons): Gross	Cost F.O.B. Plant (Million 1949 Rubles)
High Pressure (Continued)												
VR 25-1	Single cylinder topping turbine	90	500	25	3,000	31			15.6	81	89	2.75
VR 25-2	Single cylinder back-pressure	90	500	25	3,000	18			10.7	82	90	2.85
AT 25-2	Two cylinder heating	29	400	25	3,000		100	1.2 to 2.0	6.57	90		2.7

Table 20

Characteristics of Turbines with Back-Pressure for Direct Drive of Centrifugal Fans, Blast Furnace Blowers, and Centrifugal Pumps in the USSR

Type	Construction	Nominal Data				Back-Pressure (Atm)	Steam Rate (Tons per Hour)	Complete Weight (Metric Tons)		Cost (Thousand 1950 Rubles)
		Pressure (Atm)	Temperature (C)	Power (Kw)	Rpm of Turbine Shaft			Net	Gross	
AR-1-1	Single cylinder back-pressure impulse turbine with two 2-crown curtis wheels	12 29	300 400	500 to 1,000	5,000	1.2 1.2	16.0 8.0	8.0	10.0	365
AR-2-1	Single cylinder back-pressure impulse turbine with two 2-crown curtis wheels	29	400	1,700	3,000	1.2	20.7	8.0	10.0	425
AR-1-3	Single cylinder back-pressure impulse turbine with one 2-crown curtis wheel	34	420	600	5,000	9.0	13.4	7.5	9.0	375
OP-1.5-2	Single cylinder back-pressure impulse turbine with one 2-crown curtis wheel	12	275	1,500	5,000	5.0	35.0	7.5	9.0	375
OR-300	Single cylinder back-pressure impulse turbine with one 2-crown curtis wheel and hydraulic regulator	9	250	220	3,000	3.0	6.9	1.8	2.5	170

II. Technical Data on Kaplan and Francis Hydraulic Turbines.

A. Hydraulic Axial-Flow Turbines with Hinged Guide Blades. 32/

Hydraulic axial-flow turbines with hinged guide blades are used in low-head hydroelectric power stations.

B. Field of Application of Hydraulic Axial-Flow Turbines.

The hydraulic axial-flow turbines with hinged guide blades are recommended for heads from 3 to 30 meters and plants from 250 to 150,000 kw.

The turbine's runner speed depends upon the acting head and the output developed by the hydraulic turbine. In each case, however, the speed corresponds to the synchronous speed of the 3-phase 50-cps generator.

These turbines are subdivided into four series in accordance with the required speed or with the acting head and output as follows:

1. Hydraulic turbines, series K70-VB, are used for computed water heads of 3 to 7 meters in the output range of 250 to 28,000 kw.
2. Hydraulic turbines, series K90-VB, are used for heads from 6 to 18 meters in the output range of 600 to 100,000 kw.
3. Hydraulic turbines, series K245-VB, are used for heads from 14 to 22 meters in the output range of 2,000 to 125,000 kw.
4. Hydraulic turbines, series K129-VB, are used for heads from 20 to 30 meters in the output range of 3,500 to 150,000 kw.

C. Hydraulic Vertical Radial-Axial-Flow Turbines.

Hydraulic vertical radial-axial-flow turbines are used for low- and medium-head hydroelectric power stations.

D. Field of Application of Hydraulic Vertical Radial-Axial-Flow Turbines.

Hydraulic turbines with a vertical, spiral, radial-axial flow are recommended for heads from 20 to 250 meters and above in the output range from 700 to 125,000 kw.

The turbine's runner speed depends upon the acting head and the output developed by the hydraulic turbine. In each case, however, the speed corresponds to the synchronous speed of the 3-phase 50-cps generator.

These turbines are subdivided into six series corresponding to their speeds or to the acting head and output, as follows:

1. Hydraulic turbines, series F 123, are used for rated water heads of 20 to 45 meters in the output range of 700 to 125,000 kw.
2. Hydraulic turbines, series F 100, are used for heads of 40 to 70 meters in the output range of 1,250 to 125,000 kw.
3. Hydraulic turbines, series F 82, are used for heads of 60 to 100 meters in the output range of 2,500 to 125,000 kw.
4. Hydraulic turbines, series F 60, are used for heads of 65 to 120 meters in the output range of 2,000 to 125,000 kw.
5. Hydraulic turbines, series F 15, are used for heads of 85 to 170 meters in the output range of 1,500 to 125,000 kw.
6. Hydraulic turbines, series F 128, are used for heads of 110 meters and above in the output range of 1,000 to 85,000 kw.

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